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CRYSTALLOGRAPHY.—*The spinel structure: An example of variate atom equipoints.*[1] TOM. F. W. BARTH and E. POSNJAK, Geophysical Laboratory, Carnegie Institution of Washington.

The commonly accepted interpretation of the spinel structure is in some respects not in harmony with the general results of crystal analysis. For instance, it shows a distinct discrepancy with the assumption, which is well based on Goldschmidt's[2] extensive work, that the structure of a crystal is largely determined by the ratio of sizes of its constituent atoms (or ions). A few examples will readily show that in the spinel structure, with the general chemical formula XY_2O_4, the radius ratio $R_X:R_Y$ does not seem to be the important factor in determining the structure. For example, in $MgAl_2O_4$ we have $R_{Mg}:R_{Al} = 1.37$, in $CdFe_2O_4$, $R_{Cd}:R_{Fe} = 1.54$; in $K_2Cd(CN)_4$, $R_{Cd}:R_K = 0.78$, and in Mg_2TiO_4, $R_{Ti}:R_{Mg} = 0.82$. Phenacite, Be_2SiO_4, has a ratio $R_{Si}:R_{Be} = 1.15$ which lies well between the aforementioned values, nevertheless this mineral crystallizes with trigonal symmetry, and not as a spinel.

Another, and very disturbing feature of the spinel structure is that the law of constant atomic radii seems to be violated. For example, in the common spinel Mg has an apparent radius of 0.42 Å, whereas it is supposed to have the value of 0.78 Å—an enormous difference. In this connection one might think of the possibility of the spinel structure forming an atom lattice instead of an ion lattice. However, the comparison of the *differences* of the spacings of various spinels which have one metal common (like $MgAl_2O_4 - MgFe_2O_4$; $MgFe_2O_4 - CdFe_2O_4$) shows definitely that we are dealing here with an ion lattice.

Examinations of the X-ray data show conclusively that the only possible arrangements of the ions within the unit cell are (8f), (16c), and

[1] Received May 16, 1931.

[2] *Cf.* V. M. GOLDSCHMIDT. Geochem. Verteilungsgesetze VII, Vid. Akad. Oslo 1926, No. 2.

(32b). The parameter,[3] u, of the oxygen ions had been determined and found to have a value close to $\frac{3}{8}$. By choosing another value for the parameter it appeared possible to get interatomic distances that lead to more reasonable radii for the cations. However, re-calculations of the intensities show that it is hardly possible to move the positions of the oxygen atoms. In the case of $MgAl_2O_4$, for instance, the value for u appears to be good to less than $\pm$ 0.01.

The only assumption which leads to reasonable distances between oxygen and metal and at the same time is consistent with the observed intensity data is that *the 16 equivalent positions in the unit cell are not occupied by chemically equivalent ions.* Instead of having Mg in (8f) and Al in (16c) the spinel has 8 Al-ions in (8f) and 8 Al-ions + 8 Mg-ions in (16c).[4] (This arrangement will be expressed further on by writing $AlMgAlO_4$ instead of $MgAl_2O_4$.)

It was possible to test this assumption on spinels in which the two kinds of cations show a sufficient difference in their scattering power for X-rays. As such magnesium ferrite and magnesium galliate were selected. The results of the intensity calculations are given in Table 1 and prove that magnesium galliate and magnesium ferrite must have the structures $GaMgGaO_4$ and $FeMgFeO_4$; all the decisive data are in good agreement with this assumption, whereas they are quite incompatible with the formerly accepted spinel structure.

It seems to us that the demonstration of this new spinel structure is of more than ordinary interest. It brings forward a new principle in crystal analysis, or rather it causes us to give up the old idea that structurally equivalent positions have to be occupied by chemically equivalent atoms. While in the case of mixed crystals it has long been known that chemically different atoms may enter into structurally equivalent positions, no extension of this idea to pure compounds had previously been considered necessary.[5] Our study of the structure of spinels thus

[3] Determined on spinel and magnetite by W. H. BRAGG (Phil. Mag. **30**, 305, 1915), and S. Nishikawa (Proc. Math. Phys. Soc. Tokyo **8**, 199, 1915), A. Claasen (Proc. Phys. Soc. London **38**, 482, 1926); on silver molybdate by R. W. G. Wyckoff and on various complex cyanides by R. G. Dickinson (Journ. Am. Chem. Soc. **44**, 1922, pp. 1994 and 774 respectively).

[4] If one assumes that $u = 0.378$, the apparent radius of the Al-ions in (8f) is 0.46 Å, while Al^{+++} in coördination number 4 should have a value of from 0.44 to 0.47 Å. The average radius of the Mg + Al-ions in (16c) is 0.67 Å, while the radius $\frac{Mg + Al}{2}$ in coordination number 6 should be 0.675 Å.

[5] A somewhat similar idea has been proposed by A. F. Westgren and G. Phragmén (Faraday Society, *Crystal structure and chemical constitution*, p. 382, 1929) to explain the structure of intermetallic compounds.

establishes a more fundamental application of this principle. A unit cell which contains different atoms at structurally equivalent points

TABLE 1.[a] INTENSITY DATA FROM MAGNESIUM GALLIATE AND MAGNESIUM FERRITE

Indices	Magnesium galliate			Magnesium ferrite		
	Calculated		Observed	Calculated		Observed
	$MgGa_2O_4$	$Ga(MgGa)O_4$		$MgFe_2O_4$	$Fe(MgFe)O_4$	
(111)	7	0.1	0.5−	6	0.2	0.5
(113)	10	10	10	10	10	10
(133)	3	0	0	3	0	0
(333), (115)	6	6	7	6	6	7
(135)	4	0	0	3	0	0
(335)	3	3	2	3	3	2
(155), (117)	2	0	0	2	0	0
(355), (137)	6	6	4	6	6	4
(555), (157)	3	3	2	3	3	3
(357)	1	0	0	1	0	0
(159), (377)	3	3	1	3	3	1

[a] The intensities were calculated according to the formula $I = \frac{j \cdot \sqrt{A^2+B^2}}{h^2+k^2+l^2}$ disregarding the variation of scattering with the angle. The scattering power of the atoms has been taken directly proportional to the number of electrons, i.e. the atomic number minus the valence. Only faces with all indices odd are shown in the table; for such faces the expression for $\sqrt{A^2+B^2}$ becomes $4\sqrt{2}\cdot X + 8\cdot Y$ if one or all three of the indices is 3 (mod. 8) and $4\sqrt{2}\cdot X - 8\cdot Y$ if one or all three indices is 1 (mod. 8). (X and Y stand for the atoms in (8f) and (16c) respectively, and the parameter, u, of the oxygen atoms is taken as 0.375.) All other faces give approximately the same intensities for either arrangement, so it seemed unnecessary to incorporate them in this table.

may be referred to as a cell with variate atoms in equivalent positions; or, to give it a short name, a cell with variate atom equipoints. The

introduction of this conception falls in line with, and extends Machatschki's[6] ideas of the structures of silicates.

The importance of this principle for crystal analysis may, e.g., be seen from Raaz's paper[7] on the structure of gehlenite. In working out this structure he used the formula $Ca_2Al_2SiO_7$, whereas its relation to åkermanite, $Ca_2MgSi_2O_7$, would suggest that its structure possesses variate atom equipoints: $Ca_2Al(AlSi)O_7$; in this latter case the 4*e* positions of D^3_{2d} would be alternately occupied by Al and Si-ions. All chemical evidence is in agreement with this arrangement and the only reason for Raaz's unwillingness to accept it was the fact that this assumption would be contrary to the traditional application of the theory of crystal analysis.

SUMMARY

Comparisons of the observed and calculated intensities on the spinels, magnesium ferrite and magnesium galliate, show that instead of having Mg in (8f) and Al in (16c), 8 Al-ions occupy positions in (8f) and 8 Al-ions + 8 Mg-ions are in (16c). The possibility that different atoms partly replace one another in structurally equivalent positions of a crystal is in all likelihood not confined to spinels, but very likely is a more general phenomenon. It is proposed to call unit cells of such crystals, cells with variate atom equipoints.

[6] Cf. F. Machatschki. Zeitschr. f. Krist. **71**, 219. 1929; Centralblatt f. Min. Abt. A, 1930, 279.

[7] F. Raaz. Sitzungsberichte Akad. Wiss. Wien, Abt. 1, **139**, 645. 1930.

ZOOLOGY.—*Resistance of rats to superinfections with a nematode,* Nippostrongylus muris, *and an apparently similar resistance of horses to superinfection with nematodes.*[1] BENJAMIN SCHWARTZ, JOSEPH E. ALICATA and JOHN T. LUCKER, Bureau of Animal Industry, U. S. Department of Agriculture.

For the past twenty-five years parasitologists have been seeking evidence in regard to immunity in parasitic infections. By means of the known immunological technic developed in connection with the study of bacterial and related diseases, it has been possible to demonstrate more or less specific antibodies in certain diseases caused by metazoan parasites, particularly in schistosomiasis, hydatid disease, trichinosis, filariasis, and some of the worm infestations of the gastro-intestinal tract of various mammals. While the evidence obtained in the course of these investigations is of interest and of value, and shows that certain substances eliminated by the parasites involved are probably absorbed by the host with the resultant elaboration of antibodies, it falls short of explaining how the host actually copes with the parasites themselves, particularly in cases of superinfections. More recently a number of parasitologists have presented data, based on laboratory investigations, which appear to indicate that following the successive administration of infective nematode larvae to susceptible host animals, the latter ultimately become entirely refractory, or nearly so, to an infection with the particular parasites involved. The evidence presented in connection with the latter investigations has been in the main indirect, and has been based, for the most part, on information derived from quantitative studies in the form of counts, made at regular intervals of the number of worm eggs in definite amounts of the feces of experimentally infected animals, the rise and fall in the intensity of the parasitic infestations being judged by the relative number of parasite eggs present in definite quantities of feces. In the opinion of the present writers, however, evidence of this sort has definite usefulness and value, and also definite limitations. It fails to give an accurate index to the total number of worms harbored by a host, since the evidence of egg counts takes cognizance only of female worms which have attained fertile maturity, and gives no direct or positive information in regard to males, immature worms, or senile females, which might be present in the host in considerable numbers. This limitation has been pointed out from time to time in the past, but even yet is not always taken into consideration or kept in mind. The significance

[1] Received May 20, 1931.

of the possible presence of agamic parasites in a state of arrested development has been entirely overlooked in the past.

The writers' investigations on the life history of *Nippostrongylus muris*, a nematode parasitic in the small intestine of rats, and more or less closely related to pathogenic trichostrongyles occurring in domestic meat-food animals, have already brought to light facts which show rather conclusively that following the recovery from a single infection with this nematode, under rigorous experimental conditions which have precluded extraneous infections with this and with other parasites, the rat host is already in a state of relative resistance to superinfection. If exposed to a second infection or to subsequent infections, the development of the parasites is considerably retarded, but agamic worms commonly remain in the host and may ultimately come to fertile maturity, apparently a few at a time.

As first shown by Yokagawa in 1925, the infective larvae of *Nippostrongylus muris* may enter the host through the skin and be carried by the circulation to the lungs. In these organs the larvae develop for a time and then migrate to the small intestine in a manner similar to that of various species of human and carnivore hookworms, species of ascarids, and other intestinal parasites which undergo part of their development in the lungs. In about six to seven days after experimental infection with *N. muris*, the worm eggs appear in the feces of infested rats. The writers' investigations have shown that once the the eggs have appeared in the feces, their production, as followed by microscopic examination of the feces, rises rather rapidly at first, then declines gradually, and finally the eggs disappear from the feces altogether. Experimentally infected rats, killed from 13 to 16 days following infection, and about 7 to 10 days after the first appearance of eggs in the feces, contained fully grown, sexually mature worms, the females being, as a rule, at the peak of egg production, but sometimes already on the decline in production. Occasionally a few larvae, usually from three to five, have been discovered in the lungs of such rats. These larvae are worms which, for one reason or another, have failed to get into the intestine and have, therefore, been unable to develop beyond the stage which these parasites can attain in the lungs.

In experimental rats killed from 13 to 16 days following the first superinfection, subsequent to the disappearance from the feces of eggs resulting from the previous infection, the parasite picture discovered at necropsy was quite different from that noted at the corresponding stage in the course of the first infection. In some rats many of the worms from the second infection, in some cases 50 per cent or more,

were still in the lungs as third-stage larvae; the worms recovered from the intestine were, for the most part, not fully grown and many of the females had not yet attained the egg-laying stage. Before being killed, the rats in question showed an insignificant number of eggs in the feces as compared to the large number of eggs present at a corresponding stage of development in the first infection. At necropsy, the egg-producing females from the second infection were found to contain relatively few eggs in the uterus.

While direct evidence based on the finding of worms post-mortem, about two weeks after a second or a third superinfection of rats, is as yet unavailable, indirect evidence, based on the period required for eggs to appear in the feces following such successive infections, indicates that the prepatent period increases directly with the number of times that these host animals are exposed to re-infection. This is interpreted as indicating that with successive infections the host builds up an increasing resistance of a sort resulting in retardation of the growth and the development of these nematodes, possibly by elaborating, either throughout the body or, what is, perhaps, more probable, in the tissues and organs with which these worms come in contact, a specific growth-inhibiting substance or substances which retard the development of the parasites. So far as the writers are aware, this is the first experimental demonstration of what appears to be the development by the host of a growth-inhibiting mechanism for keeping in check the development and propagation of a parasitic nematode.

In connection with an investigation on the prevalence in horses of species of *Habronema*, heteroxeneous nematodes which are transmitted by flies, it was discovered that despite the absence of flies during the the winter months in the vicinity of the District of Columbia, agamic forms of *Habronema* species, in many cases no further advanced in development than that attained in their intermediate fly hosts, were present in the stomachs of horses during the months of December, 1930, to March, 1931 inclusive.[2] In the light of the experimental results obtained with *N. muris*, the writers interpret these findings in horses as probably falling within the same category of resistance as that discovered in connection with the superinfection experiments with the rat trichostrongyle discussed in this paper. It is not improbable that in cases of superinfections with other species of nematodes a growth-retarding mechanism, similar to that discovered in rats infected with *Nippostrongylus muris*, will be found.

[2] These data were collected by Mr. Allan McIntosh, Assistant Zoologist, Bureau of Animal Industry.

ZOOLOGY.—*A new species of Pinnotherid crab from Costa Rica.*[1]

MARY J. RATHBUN, United States National Museum.

In a collection of Costa Rican crabs recently sent to the United States National Museum by Prof. Manuel Valerio of San José, there is a *Pinnixa* different from any previously obtained.

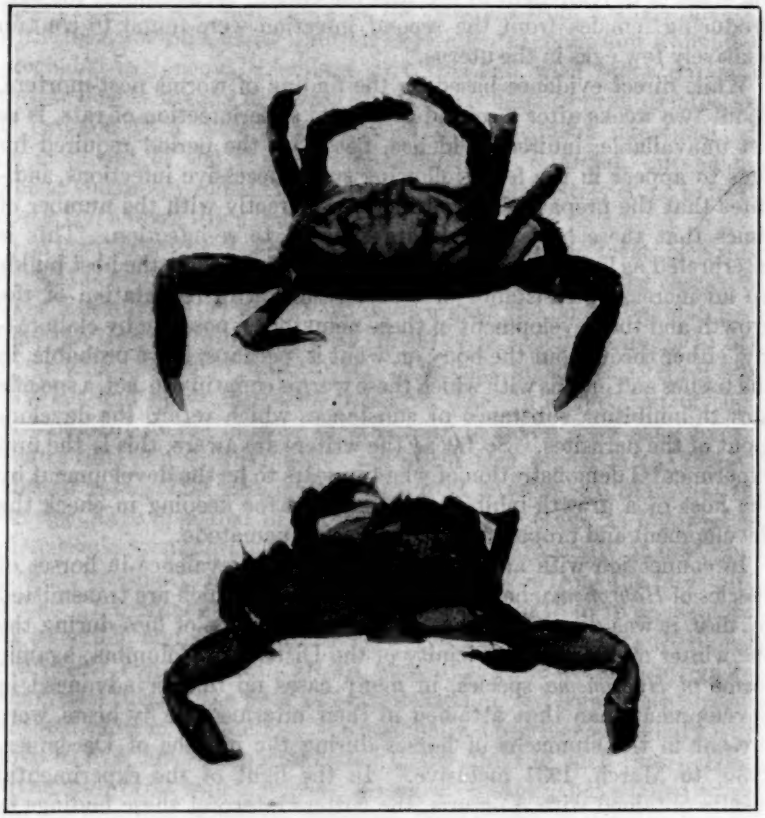


Fig. 1. *Pinnixa valerii* ♂ holotype, carapace 9.8 mm. wide, dorsal and ventral views.

Pinnixa valerii, new species

Figures 1 and 2

Carapace and appendages covered with a short close pile. Carapace nearly twice as wide as long; anterior and anterolateral margins together forming a strongly convex arch, reaching to the line of the widest part of the cardiac

[1] Published with the permission of the Secretary of the Smithsonian Institution. Received May 4, 1931.

region and meeting posterior margin at almost a right angle; posterior margin transverse at its middle for less than $\frac{1}{3}$ of carapace width. Gastric and cardiac regions strongly delimited, the former the wider; three longitudinal, narrow gastric furrows, one median, short, reaching only half way back; branchial region crossed by five obliquely transverse furrows, the hinder one deep and parallel to posterior margin. A short dorsal hepatic furrow is directed inward and forward. Eyes minute. Fronto-orbital width less than $\frac{1}{4}$ width of carapace; below the level of the orbit the carapace is vertical; the antero-lateral margin is a smooth blunt ridge, separated from the sharp pterygostomian ridge by a broad depression.

Chelipeds small, about as long as first leg, and fringed with long hair on upper margin and along middle of inner surface of carpus and manus. Chelae

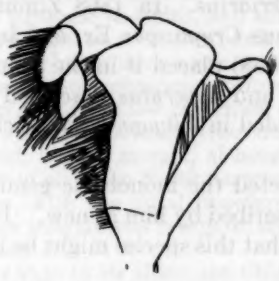


Fig. 2. Left outer maxilliped of *Pinnixa valerii* ♂ holotype, enlarged.

thin, sharp-edged; palm nearly as high as long; fingers narrow, longitudinal, acuminate, gaping in proximal two-thirds. Legs stout, first pair with remarkably short dactyl; third pair much stouter than the others, $1\frac{1}{4}$ times as long as second pair; merus widest at middle, narrowing toward either end. Male abdomen very long and narrow, overlapping buccal cavity; third, fourth and fifth segments regularly tapering, fourth and fifth equally long, sixth long and narrow, with parallel sides, seventh suboblong. Female abdomen, second to sixth segments subcircular, sixth rapidly tapering, seventh short with arcuate tip.

Male, length of carapace 5.3, width of same 9.8, width of front and orbits 2.3, of transverse posterior margin 2.8 mm.

Type-locality.—Isla San Lucas, west coast of Costa Rica; Jan. 15, 1930; 1 male holotype, 1 female, Cat No. 63854, United States National Museum.

ENTOMOLOGY.—*A revisional study of the genus* Gnathotrichus *Eichhoff in North America.*[1] M. W. BLACKMAN, Bureau of Entomology, U. S. Department of Agriculture. (Communicated by HAROLD MORRISON.)

This is the third of a series of revisional studies of *Pityophthorus* Eichh. and its allies in North America. The one remaining genus of the group, *Conophthorus* Hopk., will perhaps serve as the subject of a future study.

Gnathotrichus materiarius Fitch was described by Fitch in 1858 under the name *Tomicus materiarius.* In 1868 Zimmerman referred *materiarius* Fitch to the genus *Crypturgus* Er. and in the appendix to this same paper LeConte (1868) placed it in the genus *Cryphalus* Er. along with *retusus, sulcatus,* and *asperulus* described as new, and various other species now included in *Pityophthorus* Eichh., *Pseudopityophthorus* Sw., etc.

Eichhoff in 1868 erected the monobasic genus *Gnathotrichus* to include *G. corthyloides* described by him as new. In a footnote, however, he expressed his belief that this species might be identical with *Tomicus materiarius* Fitch.

LeConte (1876) placed *corthyloides* Eichh. as a synonym of *materiarius* Fitch, which he included, along with the other North American forms described by him, as one division of the genus *Pityophthorus* Eichh.

Eichhoff (1878) in his "Ratio Tomicinorum" placed *corthyloides* as a synonym of *materiarius* Fitch, the type of the genus thus becoming *Gnathotrichus* [*corthyloides*] *materiarius* Fitch. In this same great work Eichhoff described three additional species, *G. longipennis, G. consobrinus,* and *G. nanus,* all from Chile, and included a full redescription of the genus.

Blandford (1895) redescribed the genus and added the two new species, *G. consentaneus* and *G. bituberculatus* from Central America.

Hopkins (1902) referred to his manuscript species, *occidentalis,* which apparently has never been described, and in 1905 described *G. nitidifrons* Hopk. from Mexico.

Thus the species listed by Hagedorn (1910) are 11 in number, but *occidentalis* MS Hopk. has never been described, and *asperulus* Lec. was correctly placed by Eichhoff (1879) in the section of the genus *Pityophthorus* Eichh. which was later removed by Swaine (1918) to form the new genus *Pseudopityophthorus* Sw.

[1] Received April 16, 1931.

Swaine (1918) included in the North American members of the genus *Gnathotrichus* not only *materiarius* Fitch, *retusus* Lec., and *sulcatus* Lec., but also *asperulus* Lec., which should have been placed under *Pseudopityophthorus* Sw.

REVISED DESCRIPTION OF THE GENUS GNATHOTRICHUS EICHHOFF

Body form cylindrical, elongate, more than three times as long as wide; the surface very smooth, finely reticulate, varying from subopaque to brightly shining with the punctures varying from fine to minute.

Head with the front convex, either punctured, with the median area elevated, or convergently aciculate, with a few moderate hairs; the antenna with the club more than one and a half times as long as the five-jointed funicle, with segments 2 and 3 subequal in width, and sutures 1 and 2 septate, the females with long curved hairs on the outer border of both club and funicle; the mouth parts with slender hairs; the pregula either normal or protuberant.

Pronotum with the sides not constricted before the middle; the anterior area with numerous very broad and low asperities; the summit anterior to the middle and marked by a sharply elevated, tranverse carina; the basal border without a well-developed, beaded margin, although traces of this are to be found in some specimens of all of the North American species.

Elytra finely rugulose, with the strial punctures fine to minute and in definite rows, glabrous or subglabrous except on the posterior third; declivity weakly to strongly sulcate.

The *legs* more slender than in its allies; the tibia rather narrow and gradually widened toward the distal end, which is ornamented with two socketed teeth and in one of the sub-groups by an additional tooth on the outer edge as in other Pityophthori; the tarsi longer and more slender than in *Pityophthorus*.

The members of this genus occurring in the United States are readily recognized owing to their great similarity in general appearance. However, when studied carefully the group readily divides itself into two sub-groups separated by differences nearly as great as those separating other genera of the Pityophthori. These differences have to do with such structures as the front of the head, the pregula, the tarsi, and the tibia of the fore leg.

In *sulcatus* Lec. and *aciculatus*, new species, the front of the head in both sexes is strongly, convergently aciculate over a greater portion of its surface; while in the other group which includes *materiarius* Fitch, *denticulatus*, new species, *retusus* Lec., and *alni*, new species, the frons is punctured, with an impunctate, elevated area in the median line with either very faint or no aciculations. In *sulcatus* and *aciculatus* the pregula is normal, similar in general to the pregula of *Pityophthorus* and most of its allies. In the other group, however, the pregula is swollen and protrudes anteroventrally.

The two groups of species also differ as regards the structure of the fore legs. The general shape of the tibia is rather similar in all of the species but in the *sulcatus-aciculatus* group the submarginal teeth are confined to the distal end and are only two in number, while in the group containing *materiarius*, *denticulatus*, *retusus*, and *alni* these submarginal teeth are three in number as in all of the other Pityophthori, the third tooth being placed on the outer edge of the tibia. Other differences are to be seen in the degree of development of the serrations on the outer edge of the tibia, the modification

at the tarsal joint of the tibia in *sulcatus* and *aciculatus* to form a rudimentary subapical tooth, and in the greater length of the first tarsal joint in this same group.

These differences might be considered great enough to warrant the separation of *sulcatus* and *aciculatus* to form a new genus but the writer does not consider them of more than subgeneric value and believes the true relationship can best be expressed by dividing the genus *Gnathotrichus* into the subgenus *Gnathotrichoides*, new subgenus, including *sulcatus* and *aciculatus*, and the subgenus *Gnathotrichus*, containing the other North American species.

G. nitidifrons Hopk., described from Mexico, belongs to the true *Gnathotrichus*, with the frons not aciculate, the pregula protuberent, and the fore tibia tridentate. The position of the other described species can not be determined with certainty, as the descriptions, while excellent in other respects, do not take cognizance of the structures which the present writer considers of greatest subgeneric value. However, on the basis of frontal characters *G. consentaneus* Bldfd. seems to fall into the subgenus *Gnathotrichoides* while *G. longipennis* Eichh., *G. consobrinus* Eichh., *G. nanus* Eichh., and *G. bituberculatus* Bldfd. seem to belong to the true *Gnathotrichus*.

Added note.—Since this paper was written in its final form, the article by K. Schedl (1931) on the *Morphology of the bark-beetles of the genus* Gnathotrichus *Eich.* (Smithsonian Misc. Coll. Vol. 82, No. 10, Publication 3068; 88 pp., 40 figs.) has appeared. The author has worked out the comparative morphology of the three species known to him in accordance with a very admirable plan, and has added considerably to our knowledge of this group of Scolytidae. In most cases he has also constructed keys to the three species, based on the characters of each set of structures studied. For the most part his findings agree with those of the present writer, but in regard to the structure of the fore-leg he is certainly in error when he says on page 45,—"They (the legs) do not vary strikingly from species to species, neither in form nor in sculpture." He therefore made all of his drawings and apparently all of the descriptions from *G. materiarius*. On page 48 he says regarding the tibia,—"The sinestral margin bears four to six low serrations, and three marginal teeth which are imbedded in sockets." This is true of *materiarius* Fitch and *retusus* Lec. and also of the new species *denticulatus* and *alni*, described in the present paper, but is certainly not true of *sulcatus* Lec. and *aciculatus*, new species. These latter two species have but two "marginal" (really submarginal), socketed teeth on the fore tibia and this character serves as one of the principal differences in the subdivision of the genus as proposed by the present writer. There are also other differences in leg structure, as for instance in the greater relative length of the first tarsal segment and in a greater tendency toward the development of a subapical tibial tooth in the *sulcatus* group. But these differences are not tangible enough to lend themselves readily to use in a key.

KEY TO THE GENUS GNATHOTRICHUS EICHHOFF

A. Front of head punctured at sides, the median area elevated; antennal club with septa of sutures 1 and 2 subtransverse or weakly arcuate; the pregula protruding antero-ventrally; fore tibia with three submarginal teeth.

Subgenus *Gnathotrichus* n. sub-gen.

B. Median elevated area of frons smooth; pronotum with posterior area feebly shining, finely, sparsely punctured; elytra more narrowly rounded behind, declivity weakly or moderately sulcate, the sides feebly or moderately retuse; smaller species, less than 3.4 mm. long.

C. Antennal club with septa of sutures 1 and 2 subtransverse; pronotum more narrowly rounded in front, flattened on a triangular area just posterior to summit, posterior area sparsely, very minutely punctured; the declivity feebly sulcate, the sides not distinctly retuse, with the granules nearly obsolete; eastern species **materiarius** Fitch.

CC. Antennal club with septa weakly arcuate; pronotum moderately rounded in front; the region posterior to summit not usually flattened, the punctures moderately fine and sparse; declivity distinctly sulcate, the sides moderately retuse and distinctly denticulate; western species..... **denticulatus**, n. sp.

BB. Median elevated area of the frons feebly aciculate in the males; posterior area of pronotum at least moderately shining, the punctures moderately fine and sparse; elytra moderately rounded behind, declivity strongly sulcate, the sides strongly retuse; larger species, more than 3.5 mm. long; western species.

C. Slightly smaller, less than 3.8 mm. long; pronotum with carina marking summit shorter, moderately arcuate, and slightly in front of middle; elytra with the declivital sulcus narrower, the sides less strongly retuse, and the granules finer; the posterior margin moderately extended; living in western coniferous trees..... **retusus** Lec.

CC. Larger, usually about 4.0 mm. long; pronotum with carina longer, feebly arcuate, and more anterior in position; elytra with the declivital sulcus wider, the sides more strongly retuse, and the granules coarser; the posterior margin more strongly extended; living in western alder..... **alni**, n. sp.

AA. Front of the head distinctly convergently aciculate; antennal club with septa of sutures 1 and 2 moderately to strongly arcuate; the pregula not protruding; fore tibia with only two submarginal teeth.

Subgenus *Gnathotrichoides* n. sub-gen.

B. Antennal club with septa of sutures 1 and 2 moderately arcuate; front of head more coarsely aciculate, the punctures coarser and more evident; pronotum with the carina marking the summit moderately elevated and weakly arcuate, posterior area brightly shining, the punctures moderately fine; elytral declivity more abrupt, moderately strongly retuse, the granules coarser..... **aciculatus**, n. sp.

BB. Antennal club with septa strongly arcuate; front of head distinctly but finely aciculate, the punctures fine; pronotum with carina weakly elevated, straight and short; posterior area feebly shining, the punctures minute; elytral declivity more sloping, less strongly retuse, the granules minute..... **sulcatus** Lec.

Gnathotrichus materiarius Fitch

Figs. 1, 1a, 2, and 3

Description of the adult female.—Dark reddish brown; 3.03 mm. long, 3.29 times as long as wide.

Front of the head plano-convex, rather coarsely, strongly, moderately sparsely punctured at sides and above, with moderately fine, short hairs, median area slightly elevated, impunctate, smooth or very faintly aciculate. *Eye* moderately granulate, the inner line broadly and deeply emarginate. *Antenna* considerably lighter in color, club 1.5 times as long as funicle, 1.29 times as long as wide, widest through the second segment, the septa subtransverse; with a few very long hairs on the outer margin of the club and funicle. *Pregula* protruding antero-ventrally.

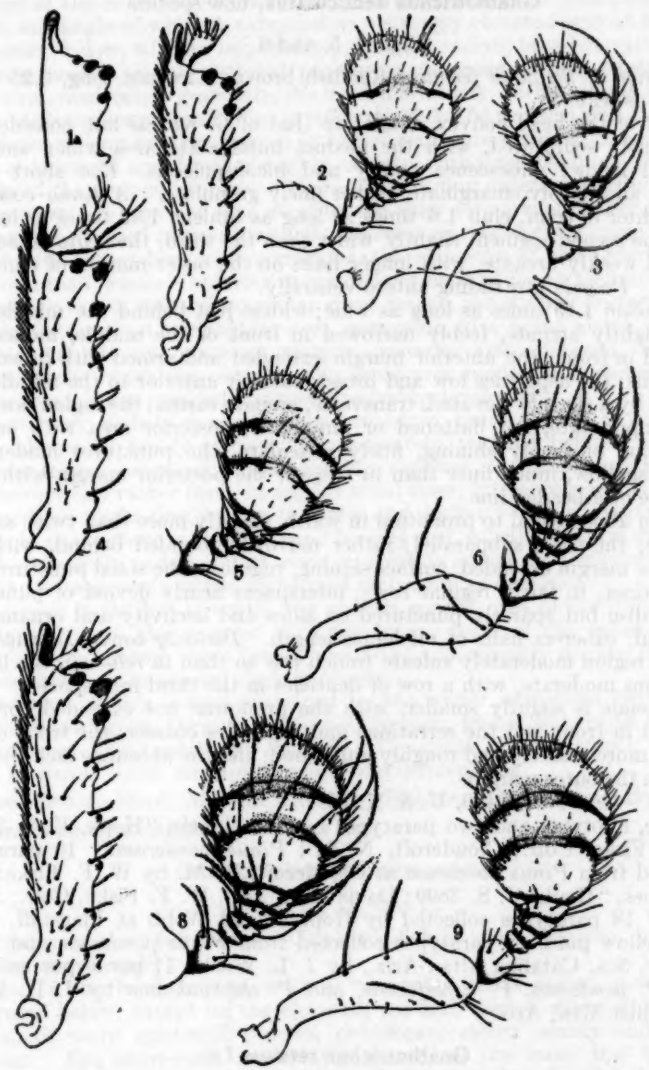
Pronotum 1.29 times as long as wide, widest near the posterior margin, the sides subparallel on the posterior half, then regularly curved to the rather narrowly rounded, slightly extended front margin, which is armed with rather low and broad serrations; anterior area with subconcentric rows of numerous, rather broad and low asperities; the summit modified to form a distinct, well-developed, arcuate, transverse carina, anterior to the middle; the surface posterior to it depressed to form a shallow, median, triangular impression which tapers posteriorly and is lost about half way between summit and posterior margin; posterior area feebly shining, the surface very finely reticulate, minutely, rather sparsely punctulate, glabrous; the beaded marginal line feebly developed.

Elytra nearly exactly twice as long as wide, the sides subparallel, narrowly rounded behind, with the posterior margin extended; surface moderately shining, rugulose; the strial punctures very fine, in fairly regular rows, interstrial punctures still more minute, very sparse on the disc, which is nearly glabrous, more numerous, and bearing stiff erect hairs of moderate length on the declivity. *Declivity* convex, weakly sulcate in the sutural region, the suture flat, lateral elevations weak, with a few small, nearly obsolete granules.

The *male* is similar in size, proportions, and sculpture, but with the pronotum more broadly rounded in front, and the anterior margin not extended; it is readily distinguished by the absence of the longer hairs on the outer margin of the antennal funicle and club.

The foregoing description of the female was prepared, with the exceptions of the measurements of the antenna, from a specimen now in the National Museum but obtained from the Fitch Collection and bearing the label "*Tomicus materiarius*, Fitch" in Fitch's own hand-writing. It is believed that this specimen served as the type for Fitch's original description.

This species is widely distributed over eastern Canada and the eastern part of the United States. The writer has examined several hundred specimens from the following States: Ontario, Canada, Maine, Vermont, Massachusetts, New York, Pennsylvania, Michigan, Wisconsin, Minnesota, Nebraska, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Mississippi, Louisiana, Arkansas, and Texas. The hosts are the various species of *Pinus*, *Picea*, *Larix*, *Abies*, and *Tsuga* occurring in its range. Other conifers used in plantations or as ornamentals are also subject to attack.



FIGURES.—1. Fore tibia of *Gnathotrichus materiarius* Fitch;—1a. fore tibia of same showing extra tooth on distal end.—2. Antenna of male *G. materiarius*.—3. Antenna of female *G. materiarius*.—4. Fore tibia of *G. denticulatus* n. sp.—5. Antenna of male *G. denticulatus* n. sp.—6. Antenna of female *G. denticulatus* n. sp.—7. Fore tibia of *G. retusus* Lec.—8. Antenna of female *G. retusus*.—9. Antenna of male *G. retusus*.

All figures were made by the writer from preparations mounted in balsam, using a compound microscope and a camera lucida. All are magnified about 112 diameters.

Gnathotrichus denticulatus, new species

Figs. 4, 5, and 6

Description of the adult female.—Reddish brown; 3.28 mm. long, 3.25 times as long as wide.

Front of the head convex, similar to that of *G. retusus* but considerably more finely sculptured, with the median impunctate area wider and less elevated below; pubescence scanty and inconspicuous. *Eye* short oval, broadly and deeply emarginate, rather finely granulate. *Antenna* considerably lighter in color, club 1.6 times as long as funicle, 1.32 times as long as wide, the second segment slightly wider than the third, the septa of sutures 1 and 2 weekly arcuate, with longer hairs on the outer margin of club and funicle. *Pregula* protruding antero-ventrally.

Pronotum 1.19 times as long as wide; widest just behind the middle, the sides slightly arcuate, feebly narrowed in front of the middle, moderately rounded in front; the anterior margin extended and armed with broad, low serrations; the asperities low and broad; summit anterior to the middle and marked by a sharply elevated, transverse, arcuate carina; the region posterior to it impunctate, not flattened or impressed; posterior area with surface subopaque or feebly shining, finely reticulate, the punctures moderately sparse, shallow, much finer than in *retusus;* the posterior margin with little evidence of a beaded line.

Elytra about equal to pronotum in width, slightly more than twice as long as wide; the sides subparallel; rather narrowly rounded behind, with the posterior margin extended; surface shining, rugulose; the strial punctures fine but distinct, in fairly regular rows; interspaces nearly devoid of punctures on the disc but sparsely punctured on sides and declivity and ornamented with stiff, suberect hairs of moderate length. *Declivity* convex, abrupt; the sutural region moderately sulcate (much less so than in *retusus*), the lateral elevations moderate, with a row of denticles in the third interspace.

The *male* is slightly smaller, with the pronotum not extended, broadly rounded in front and the serrations and asperities coarser; the front of the head is more coarsely and roughly punctured, and the antennae lack the long hairs on the outer margin.

Type.—Cat. No. 43430, U. S. N. M.

Type, allotype, and two paratypes bear the labels, "Hopk, U. S. 3984f; W. F. Fiske, Colr.; Cloudcroft, N. M.; *Pinus ponderosa:*" 10 paratypes collected from *Pinus ponderosa* at Cloudcroft, N. M. by W. F. Fiske: four paratypes, "Hopk. U. S. 3899; Davis Mts., Tex., W. F. Fiske, Colr.; *Pinus edulis:*" 18 paratypes collected by Hopkins and Webb at Flagstaff, Ariz., from yellow pine: 18 paratypes collected from *Pinus ponderosa* and *Abies concolor*, Sta. Catalina Mts., Ariz., by J. L. Webb: 11 paratypes collected from *P. ponderosa*, *P. strobiformis*, and *P. chichuahuana* by J. L. Webb, Chiricahua Mts., Ariz.

Gnathotrichus retusus Lec.

Figs. 7, 8, and 9

Description of the adult female.—Dark reddish-brown, with the anterior part of pronotum and of elytra slightly lighter in color; 3.5 to 3.8 mm. long, 3.25 times as long as wide.

Front of the head convex, moderately punctured, with a triangular callus above, one angle of which is extended as a strongly elevated smooth ridge on the vertex; below, with an impunctate, shining, median, broad elevation ending in a small, acute epistomal process; pubescence rather scanty. *Eye* short-oval, moderately granulate, the inner line widely, rather deeply emarginate. *Antenna* somewhat lighter in color, the club 1.54 times as long as funicle, 1.23 times as long as wide; second and third segments subequal in width, the septa of sutures 1 and 2 rather weakly arcuate; with longer hairs on the outer margin of the club and funicle. *Pregula* protruding antero-ventrally.

Pronotum 1.29 times as long as wide; the sides subparallel, feebly arcuate, moderately rounded in front, with the anterior margin slightly extended and armed with rather low, wide serrations; the asperities of the anterior area low and broad; summit anterior to middle and marked by an arcuate, rather strongly elevated, transverse, rather short carina, the surface posterior to it slightly flattened on a triangular area narrowing to a point about midway between summit and posterior margin; posterior area glabrous, with the surface finely reticulate, shining, the punctures moderately sparse, deep, and moderately fine; beaded marginal line feebly developed.

Elytra very slightly narrower than pronotum, twice as long as wide, the sides subparallel, feebly converging, moderately rounded behind, with the posterior margin extended; surface shining, rugulose; the strial punctures fine but distinct and rather deep, in regular strial rows; interspaces nearly devoid of punctures on the disc, but on the sides and declivity with a few punctures similar in size to those of the striae and bearing stiff, suberect hairs of moderate length. *Declivity* rather abrupt, convex, strongly sulcate in the sutural area, with the sides strongly retuse and armed with a row of denticles.

The *male* is similar, but with the median carinal area of the frons finely, weakly aciculate, the antenna with the longer hairs of the outer margin absent; the pronotum more broadly rounded and strongly serrate in front, and the sculpture in general slightly coarser.

Specimens of this species examined by the writer were from British Columbia, Washington, Oregon, California, Nevada, Idaho, and South Dakota. The hosts are *Pinus ponderosa, P. jeffreyi, P. radiata, P. lambertiana, Pseudotsuga taxifolia, Abies magnifica,* and *Tsuga heterophylla.*

G. occidentalis Hopk. MS., mentioned by Hopkins (1902) but not described, appears to be identical with *G. retusus* Lec.

Gnathotrichus alni, new species

Figs. 10, 11, and 12

Description of the adult female.—Dark reddish-brown; 4.04 mm. long, 3.4 times as long as wide.

Front of the head convex, with a triangular callus above, moderately punctured below, except on the elevated, median, carinal space which ends in a small sharp epistomal process, pubescence rather scanty and inconspicuous. *Eye* short-oval, moderately granulate, the inner line broadly, moderately deeply emarginate. *Antenna* lighter in color, the club 1.8 times as long as funicle, 1.3 times as long as wide, second and third segments subequal in width, the septa of sutures 1 and 2 rather weakly arcuate; with a few longer hairs on the outer margin of club and funicle. *Pregula* lighter in color, except on the anterior margin, strongly protruding antero-ventrally.

Pronotum 1.26 times as long as wide, widest near the posterior border, the sides subparallel, feebly converging anteriorly; moderately rounded in front; with the anterior margin extended and armed with very broad, low serrations, asperities very low and broad; summit anterior to the middle, marked by an arcuate, rather strongly elevated carina, longer than in *retusus*, the surface posterior to it slightly flattened on a triangular area which narrows to a point about half way to the posterior border; posterior area glabrous, with the surface finely reticulate, moderately shining, the punctures moderately fine, rather deep, moderately sparse.

Elytra slightly narrower than pronotum, 2.18 times as long as wide, the sides straight and feebly converging, moderately narrowly rounded behind, more narrowly than in *retusus*, with the posterior margin extended; surface brightly shining, rugulose, the strial punctures fine, rather deep, in regular strial rows; interspaces nearly devoid of punctures and nearly glabrous on the disc, more numerous on the sides and declivity, similar in size to those of the striae and bearing stiff, suberect hairs of moderate length. *Declivity* moderately abrupt, less so than in *retusus*, convex, strongly sulcate in the sutural area, more widely than in *retusus*, with the sides strongly retuse and armed with a row of denticles.

The *male* is similar but has the carinal area of the frons weakly and finely aciculate; the antennae lack the longer hairs on the outer margin; the pronotum is more broadly rounded and strongly serrate in front, with the anterior margin not so much extended, and in general the sculpture is slightly coarser.

Type.—Cat. No. 43431, U. S. N. M.

Type, allotype, and three paratypes bear the labels—"Hopk. U. S. 1868a; Burke, Colr., Hoquiam, Wn.; *Alnus;*" one paratype—"Hopk. U. S. 2020; Burke, Colr., Satspo, Wn.; *Alnus oregona;*" one paratype—"Hopk. U. S. 2369a, Hopkins, colr., Hoquiam, Wn.;" one paratype—"Hopk. U. S. 4007a; Burke, Colr., Hoquiam, Wn.; *Alnus oregona;*" one paratype—"Hopk. U. S 4217b; Burke, Colr., Miller Lg., Wn.; *Alnus oregona:*" one paratype—"Webb 116e; Sequim, Wash.; *Alnus*: J. L. Webb, Colr."

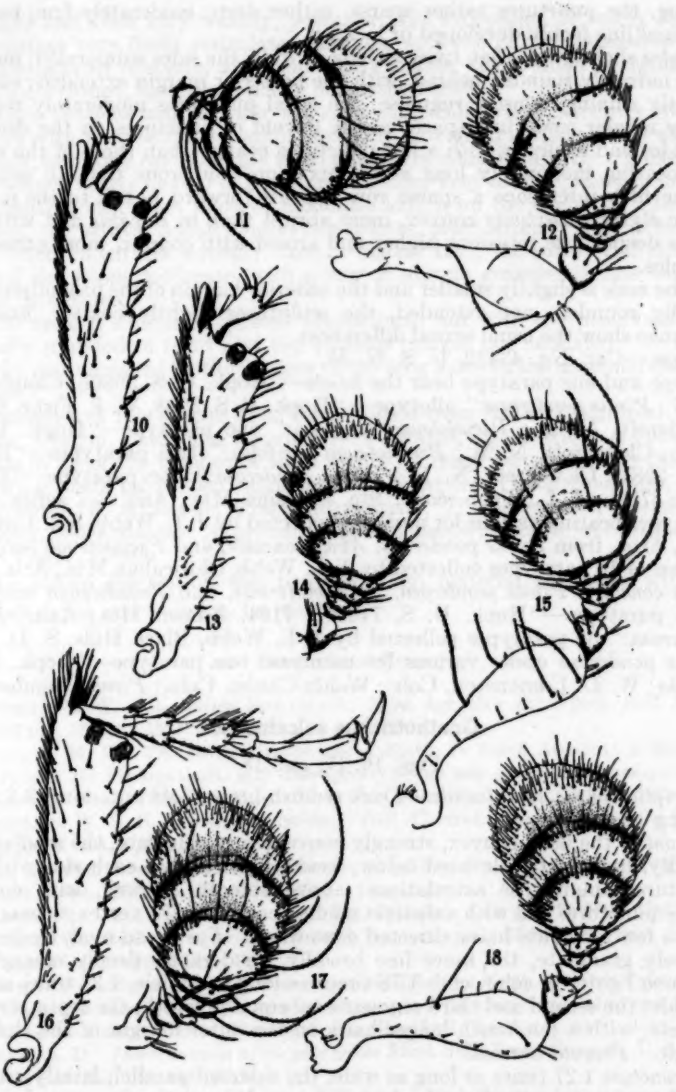
Gnathotrichus aciculatus, new species

Figs. 13, 14, and 15

Description of the adult female.—Dark reddish-brown; 3.54 mm. long, 3.24 times as long as wide.

Front of head similar to that of *G. sulcatus* Lec. but with the aciculations coarser, more coarsely and evidently punctured, and not so deep. *Eye* broad oval, moderately coarsely granulate, the inner line broadly and deeply emarginate. *Antenna* somewhat lighter in color; the club 1.79 times as long as funicle, 1.3 times as long as wide, the second and third segments subequal in width, the septa moderately arcuate, with the usual development of long hairs on the outer margin of club and funicle. *Pregula* normal.

Pronotum 1.28 times as long as wide, the sides subparallel, very feebly arcuate, the front margin distinctly extended, rather narrowly rounded, and armed with moderately broad low serrations, more numerous and sharper than in *sulcatus*; anterior area with the asperities low and broad but much stronger than in *sulcatus*; the transverse carina marking the summit moderately elevated, moderately short, weakly arcuate; the surface posterior to it not modified; posterior area glabrous, with the surface very finely reticulate,



FIGURES.—10. Fore tibia of *Gnathotrichus alni* n. sp.—11. Antenna of female *G. alni* n. sp.—12 Antenna of male *G. alni* n. sp.—13. Fore tibia of *G. aciculatus* n. sp.—14 Antenna of male *G. aciculatus* n. sp.—15. Antenna of female *G. aciculatus* n. sp.—16. Fore tibia of *G. sulcatus* Lec.—17. Antenna of female *G. sulcatus*.—18. Antenna of male *G. sulcatus*.

See note to figures 1-9.

shining, the punctures rather sparse, rather deep, moderately fine; beaded marginal line feebly developed or lacking.

Elytra slightly less than twice as long as wide, the sides subparallel, moderately narrowly rounded behind, with the posterior margin extended; surface brightly shining, densely rugulose; the strial punctures moderately fine, in nearly regular rows; interspaces nearly devoid of punctures on the disc; on the sides and declivity with a few punctures coarser than those of the striae and bearing moderately long stiff hairs more numerous than in *sulcatus*. In the fifth interspace a sparse row extends forward nearly to the middle of the elytra. *Declivity* convex, more abrupt than in *sulcatus* and with the sulcus deeper, the retusions higher and armed with coarser, more numerous granules.

The *male* is slightly smaller and the anterior margin of the pronotum more broadly rounded, not extended, the sculptures slightly coarser, and the antennae show the usual sexual differences.

Type.—Cat. No. 43432, U. S. N. M.

Type and one paratype bear the labels—"Hopk. U. S. 3986b, Cloudcroft, N. M.; *Pinus ponderosa:*" allotype—"Hopk. U. S. 3988, W. F. Fiske, Colr.; Cloudcroft, N. M.; *Pseudotsuga taxifolia;*" one paratype—"Hopk. U. S. 3981b; Cloudcroft, N. M.; *Pseudotsuga taxifolia:*" two paratypes—"Hopk. U. S. 3984f; Cloudcroft, N. M.; *Pinus ponderosa:*" one paratype—"Hopk. U. S. 5708b; J. L. Webb, colr.: Sta. Catalina Mts., Ariz.:" a series of 14 paratypes bearing various lot numbers collected by J. L. Webb, Sta. Catalina Mts., Ariz., from *Pinus ponderosa, Abies concolor,* and *Pseudotsuga taxifolia*: a series of 16 paratypes collected by J. L. Webb, Chiricahua Mts., Ariz. from *Abies concolor, Pinus ponderosa, P. strobiformis,* and *Pseudotsuga taxifolia*: three paratypes—"Hopk. U. S. 7160 & 7164, Rincon Mts., Ariz.; *Pinus ponderosa:*" 54 paratypes collected by J. L. Webb, Black Hills, S. D. from *Pinus ponderosa* under various lot numbers: one paratype—"Hopk. U. S. 12436q; W. D. Edmonston, Colr.; Waldo Canon, Colo.; *Pinus scopulorum.*"

Gnathotrichus sulcatus Lec.

Figs. 16, 17, and 18

Description of the adult female.—Dark reddish-brown 3.48 mm. long, 3.3 times as long as wide.

Front of the head convex, strongly convergently aciculate, the median area broadly, indistinctly elevated below, weakly flattened at each side with fine punctures among the aciculations; above smooth, shining, with coarser, sparse punctures and with a distinct median carina on the vertex; ornamented with a few moderate hairs, directed downward. *Eye* broad oval, moderately coarsely granulate, the inner line broadly, moderately deeply emarginate. *Antenna* lighter in color, club 1.78 times as long as funicle, 1.33 times as long as wide; the second and third segments subequal in width, the septa strongly arcuate; with a few much longer hairs on the outer margin of the club and funicle. *Pregula* normal.

Pronotum 1.27 times as long as wide, the sides subparallel, faintly arcuate, the front margin moderately broadly rounded, distinctly extended, and armed with very broad and very low serrations; anterior area with the subconcentric rows of asperities very low and very broad, the summit anterior to the middle and marked with a short, straight, feebly elevated, transverse carina, the surface posterior to it not flattened or impressed except occa-

sionally and then very weakly; posterior area subopaque or feebly shining, the surface very finely reticulate, glabrous, with the punctures shallow, very minute, almost obsolete, and moderately sparse, the beaded marginal line feebly developed, sometimes not to be distinguished.

Elytra twice as long as wide, the sides subparallel, very narrowly rounded behind with the posterior margin distinctly extended; surface feebly shining, densely, minutely rugulose; the strial punctures minute, in fairly regular rows; interspaces nearly devoid of punctures on disc, very minute, more numerous, and bearing stiff erect hairs of moderate length on the declivity. *Declivity* convex, the sutural region moderately sulcate, more strongly than in *materiarius* Fitch, much less strongly than in *retusus* Lec., the suture not elevated, lateral elevations moderate, with a row of minute granules in line with the third interspace.

The *male* is similar in general proportions, but with the pronotum more broadly rounded in front and the anterior margin not extended. It is also readily distinguished by the absence of the long hairs on the antennal club and funicle.

Examples of this species have been studied from British Columbia, Washington, Oregon, California, Arizona, New Mexico, and Mexico. It probably breeds in all of the coniferous trees within its range but specimens from the following hosts have been examined by the writer: *Pinus ponderosa, Picea engelmanni, P. sitchensis, Tsuga heterophylla, T. mertensiana, Pseudotsuga taxifolia, Abies concolor, A. grandis, Sequioia sempervirens, S. washingtoniana,* and *Thuja plicata.*

The above description was prepared from material compared with LeConte's types and found to be identical.

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PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

PHILOSOPHICAL SOCIETY

1015TH MEETING

The 1015th meeting was held in the Cosmos Club Auditorium, Saturday evening, January 17, 1931. The meeting was called to order at 8:15 P.M. by President CURTIS.

Program: E. O. HULBURT: *The zodiacal light* (illustrated).—Variations in the zodiacal light, from the observations of Jones in 1853–1855 and of more recent observers, are shown to occur during magnetic storms. This indicates that the commonly accepted planet-dust theory of the zodiacal light is untenable and opens the way to an atmospheric theory which is developed quantitatively. Neutral atoms and molecules sprayed out in all directions from the earth's atmosphere are ionized at 50,000 to 70,000-kilometer levels by the ultra-violet light of the sun. Because of the wobble of the earth's magnetic field with the rotation of the earth, ions near the equatorial plane stay for some time at these high levels to form a ring around the earth, and ions at high latitudes fall quickly back to the earth to give aurorae. The gravitational magnetic drift of the ions forces the ion ring into a long oval stretching out away from the sun to 10^6 kilometers. The pressure of the sunlight warps the oval into the plane of the ecliptic and makes the ions stream out like a comet's tail. The ions are fluorescent; they absorb the sun's ultra-violet light and emit a part of the absorbed energy as visible light. The oval ring is the zodiacal light; the comet-tail ion stream is the gegenschein. The zodiacal cones in December are somewhat to the south of the cones in June; the evening cone is south and north of the morning cone in March and September, respectively. These theoretical inferences are in accord with observation. (*Author's abstract.*)

Discussed by Messrs. WHITE, GISH, and CURTIS.

H. T. WENSEL: *The Waidner-Burgess standard of light and the freezing point of platinum* (illustrated).—The unit of light is at present maintained by carbon filament lamps deposited in the various national laboratories. The unit of light is therefore subject to any drift that may occur in the brightness of these standard lamps.

Various sources, more or less reproducible from specifications, have been studied from time to time, but none has been found reproducible enough for use as a standard. The carbon lamps were adopted in 1909 primarily because it was felt that their drift with time would be sufficiently small so that it would be many years before the uncertainty in the unit would reach the magnitude of the uncertainties in the unit as represented by those sources, "reproducible" from specifications, which were then available. It was recognized, however, that in time the carbon lamps would have to be superseded by some reproducible standard.

In 1908 Waidner and Burgess suggested the use of a black body immersed in a bath of freezing platinum as a standard of candlepower. This suggestion has been experimentally carried out. The platinum was contained in crucibles of fused thorium oxide and heated in a high-frequency induction furnace. The immersed black body was made of fused thorium oxide. The source as set up was found, by comparison with standard carbon filament lamps, to be reproducible within the limits detected photometrically.

The brightness of the immersed black body was found to be 58.84 candles per cm.^{2} during the freezing of the platinum. Measurements of the temperature with an optical pyrometer yielded 1773.5°C. From these results the least mechanical equivalent of light may be computed as 0.001603 watt per lumen. (*Author's abstract.*)

Discussed by Mr. WHITE.

1016TH MEETING

The 1016th meeting was held in the Cosmos Club Auditorium, Saturday evening, January 31, 1931. The meeting was called to order at 8:15 P.M. by President CURTIS.

Program: V. L. CHRISLER and W. F. SNYDER: *The measurement of sound absorption* (illustrated).—The common interest of the acoustical laboratory, the architect, and the manufacturer of sound-absorption materials demands a measurement of the sound-absorbing qualities of the various materials. The term, *coefficient of absorption*, is used as a basis for comparison and is simply the fractional part of the sound energy absorbed at each reflection.

There are two general methods of making sound-absorption measurements, —the tube and the reverberation method—each of which has several modifications. The tube method is now practically obsolete because of inherent characteristics which fail to bring it into agreement with the more accepted reverberation method.

Although Wallace Sabine of Harvard University had made many experimental determinations by the reverberation method it was not until 1911 that Jaeger developed a satisfactory mathematical analysis of the problem.

The usual method of making these measurements has been by the ear—listening for the sound to decay from some definite intensity level to the threshold of audibility. To calibrate a room it is necessary to change the intensity of the sound and Sabine used one, two, three, and four organ pipes to make this change. Recent developments in loud speakers and amplifiers make it possible to work through a range of intensity shifts of several thousand; consequently the time differences are larger and the accuracy is increased. When using the ear it is necessary to make about 1000 stop-watch observations to determine the coefficient of absorption of a material at six frequencies. This is a rather laborious and time-consuming procedure.

The general equation can be put into a form that will yield an absorption value by measurement of the rate of decay of the sound in the room. Picking up the decaying sound with a microphone and recording it on an oscillograph has met with some success but it is also a time-consuming process. At present a purely instrumental method is being used at the Bureau of Standards. The initial intensity of sound and an arbitrary setting of the recording instrument determines two sound levels whose time difference is recorded by an electric clock that is automatically started and stopped. Very rapid observations can be made and therefore a statistical method is possible. This is desirable in sound measurements. (*Author's abstract*).

Discussed by Messrs. HEYL, HUMPHREYS, TUCKERMAN, and CURTIS.

R. H. CANFIELD: *Internal friction in metals* (illustrated).—This paper is a resumé of the author's experiments and an account of his experimental methods.

The property known as *internal friction* or *elastic hysteresis* is due to an imperfection in the elastic properties of materials, such that the stress is higher when the strain is increasing than it is when the strain is decreasing. Thus the stress-strain diagram of a specimen carried through a cycle of stress, varying from zero to $+f$ to zero to $-f$ to zero, is a loop instead of a straight line as it would be if Hooke's law were precisely true. It is difficult to determine the form of this loop by static tests and extensometer measurements. On the other hand it is easy to measure the *area* of the loop, since this is the portion of energy dissipated as heat during the stress-cycle. It has ordinarily been the custom to make this measurement by measuring the rate of decay of vibrations of an elastically controlled pendulum. The disadvantage of this method is that during the course of the experiment the stress-amplitude changes by a considerable amount, so that the value of the dissipation constant is an average over a range of stresses and not a unique value for a single stress. This is undesirable because, as the author's experiments show, the internal friction undergoes rather abrupt changes at certain stress-amplitudes.

The author's method, without entering into details, uses the phenomenon of forced vibrations at constant amplitudes. Under these conditions the elastic pendulum is supplied with a fixed amount of energy at each vibration, this energy being exactly equal to the work dissipated by internal friction during one cycle. This energy is actually supplied by magnetic forces, and the principal experimental problem is to determine what the work done by these forces actually is. The present method of driving involves the use of a subsidiary pendulum loosely coupled to the main one and carrying contacts which control the admission of current into the magnet windings through a vacuum-tube valve circuit. Adjustable oil cups act on damping vanes attached to the subsidiary pendulum so as to permit the exact adjustment of the phase relation between the two vibrations necessary for maximum amplitude. The forces due to the magnetic field are determined once for all by static measurements.

The experimental results cannot be described in actual detail here. They show that it is possible to duplicate results with different pieces of apparatus and different-sized specimens of the same material. They also bring to light very interesting relations between the internal friction and the mechanical history. Such treatments as cold working, fatigue, and precipitation hardening, reveal themselves by marked changes in the internal-friction "diagram."

The internal-friction diagram, just referred to, is considered by the author to be the most advantageous way of displaying his experimental results. The ordinate of a point on this curve, called the *elastic stress*, is the stress-amplitude of the cycle. The abscissa is the *friction stress*, defined as the half-width of the elastic hysteresis loop, considered to be a parallelogram such that its area is equal to the loss of energy for the stress-cycle in question. The diagram is often approximately linear. In such cases the cotangent of the slope angle is the ratio of internal-friction stress to elastic stress, and can be termed the *coefficient of internal friction* in complete analogy to the common definition of the coefficient of surface friction. (*Author's abstract.*)

Discussed by Messrs. CURTIS, BROMBACHER, and BRICKWEDDE.

1017TH MEETING

The 1017th meeting was held in the Cosmos Club Auditorium, Saturday evening, February 14, 1931. The meeting was called to order at 8:17 P.M. by President CURTIS.

Program: F. L. MOHLER and C. BOECKNER: *The radiation from metal surfaces under low-speed electron bombardment* (illustrated).—A small probe surface in the highly ionized region of a discharge may draw an electron current of several amperes per cm.^{2} at any positive potential relative to the surrounding space. Under such conditions the metal probe surface emits a continuous spectrum radiation. This has been observed in helium, potassium, and caesium discharges and studied quantitatively in the last case. The spectrum of copper radiation at 7 volts shows an approximately equal energy distribution with an absolute value at 3700 AU of 3×10^{-14} ergs per cm.^{2} per sec per unit frequency range for a current density of 1.4 amperes per cm.^{2}. The intensity distribution remains nearly the same between 5 and 20 volts but below 4 volts has a frequency limit in the ultra-violet. This threshold frequency ν_0 depends on the voltage V by the relation

$$h\nu_0 = e\,(V + W)$$

where W (presumably the work function of the caesiated metal) has values of 1.95 volts for copper, 2.1 volts for silver, and 1.45 volts for tungsten. The intensity-voltage curves increase rapidly up to 7 volts and very slowly beyond. The radiation can be considered as analogous to the continuous X-ray spectrum. The general equation for X-ray intensity as a function of voltage predicts an intensity for Cu at 7 volts and 3700 AU of 1.85×10^{-14} ergs in satisfactory agreement with the observed value of 3×10^{-14}. A theoretical relation between the photoelectric effect and the converse process also leads to an agreement in order of magnitude with the observed intensities. (*Author's abstract.*)

Discussed by BRICKWEDDE.

F. E. WRIGHT: *Optical methods for reducing the effects of photographic-plate grain* (illustrated).—The image on a photographic plate consists of clumps and aggregates of minute particles of silver scattered through the gelatine film. At points where the silver particles are closely packed, the plate is dark. In making measurements on photographic images, the accuracy of the setting depends on a number of factors, of which one of the most disturbing is the presence of a large grain or clump of silver particles. A more exact measurement could be made if this effect of prominent grains were suppressed, even if only partially.

In the case of spectral lines which are straight and parallel different optical methods can be used for suppressing or fusing the prominent grains: (1) The image itself can be made to vibrate rapidly parallel with the spectral lines (method of Linnik). (2) Each object point can be drawn out into an image line parallel with the spectral lines by means of a cylindrical lens (method of Anderson). (3) Each object point can be elongated into a short image line by inserting a tilted glass plate between the objective of the observing microscope and the photographic plate. (4) Each object point can be elongated into a short line in the image by use of a single or multiple narrow slit-diaphragm above the objective. (5) Two images of each spectral line are produced and the one is superimposed on the second, but slightly shifted along the spectral line (Wollaston prism method). (6) The plate is viewed under dark-ground illumination. Each silver grain or clump becomes a luminous image point on which it is easy to make an accurate setting.

The fusing of grains that mark the position of the image of a star can be effected by reducing the resolving power of the imaging microscope objective either by the use of an iris diaphragm in the rear focal plane of the objective or by first forming a minified image of the plate and then observing this image under suitable magnification. In each case the resolving power of the optical system is so much reduced that silver particles separated by a short distance no longer appear as separate points in the image. Another method of fusion is to cause the image to vibrate in rapid circulatory motion; the diameter of the small vibration circle should be about equal to the average distance between the silver particles in a star's image. This movement is most readily accomplished by use of a weak lens mounted in an iron ring suspended by three elastic wires in front of the objective. The iron ring is set in motion by two electromagnets set 90° apart and actuated by alternating currents, the phase of the two currents differing by 90°. The 60-cycle alternating current causes the ring to oscillate so rapidly that the image appears stationary and fused.

These methods for decreasing graininess in special parts of a photographic plate enhance the accuracy of measurement several fold and at the same time decrease eye-strain to an appreciable extent. (*Author's abstract.*)

Discussed by Mr. HUMPHREYS.

Two short informal communications were given by Messrs. TUCKERMAN and DRYDEN, and a report made by HUMPHREYS.

1018TH MEETING

The 1018th meeting was held in the Cosmos Club Auditorium, Saturday evening, February 28, 1931. The meeting was called to order at 8:20 P.M. by President CURTIS.

Program: F. T. DAVIES: *Aurora australis observed on the Byrd Antarctic Expedition* (illustrated).—Observations of both aurora borealis and australis indicate an auroral zone in either hemisphere and a belt within each of the zones in which auroral displays are most frequent. In the north, this maximum-frequency belt is situated at about 23° from the point in which the axis of the earth's uniform magnetic field meets the surface. This point is not the magnetic pole, however.

Analysis of the auroral records of antarctic expeditions shows that a similar distribution of auroral frequency occurs in the southern hemisphere centered approximately on the opposite projection of the earth's magnetic axis.

In the northern hemisphere, observations have been made of aurora for a very long time and in many localities both north and south of the maximum-frequency belt. In the south, on the contrary, observations have been taken largely south of the maximum-frequency belt and these over a total period of some thirty years. Although the aurora australis has been seen occasionally in the countries of the southern hemisphere, these countries are separated from the antarctic by wide stretches of ocean, little traversed by ships, so that only exceptionally widely spread auroras are observed north of the antarctic maximum-frequency belt. Thus in the study of the aurora borealis, the observations of polar expeditions are supplemented by considerable observational data in temperate latitudes, while our knowledge of the aurora australis is derived chiefly from the records of the few expeditions that have wintered on the antarctic continent.

The following expeditions made regular systematic auroral observations: The Borchgrevink Expedition, 1899, Cape Adare; the Scott Expeditions, 1902–03 and 1911–12, McMurdo Sound and Cape Adare; the German Expedition under Drygalski, 1902, Kaiser-Wilhelm Land; Shackleton Expedition, 1908, McMurdo Sound; the Mawson Expedition, 1912–13, Addie Land and Macquarie Island; and the Byrd Expedition, 1929, Bay of Whales. All of these bases with the exception of Macquarie Island were within the belt of maximum frequency.

The aurora australis exhibits similar phenomena to the aurora borealis so that the terminology is the same for both. The fact that McMurdo Sound, the base for three of the above expeditions, is a considerable distance from the maximum belt, has given the impression that the aurora australis is much less brilliant than the aurora borealis. Mawson's bases, the German base, and our own were also well within this zone but the Cape Adare observations show that the aurora australis as seen from that position is much brighter, more colored, and more active than as seen from any of the other positions.

At Little America the aurora australis was first seen on the night of March 16–17, 1929. A regular 24-hour watch was instituted on April 3 and kept up for the remainder of the year. The observations taken at half-hourly intervals between April 3 and September 26 at which date an aurora was last seen, form the basis of analysis. A single observation included mention of time (165° meridian east of Greenwich); intensity of display on a scale 0–4, "0" meaning not seen and "4" brilliant; form, that is, glow, arch, curtain, rays and streamers, or corona; direction; altitude; and color. The amount of cloud and the intensity of moonlight were also noted.

It was found that of all clear or only partly cloudy nights an aurora was seen on over 90 per cent of the time. A better estimate of occurrence, however, is the proportion of half-hourly observations when an aurora was seen (1412 times) to the number when conditions of cloud and light were such as would allow it to be seen. This proportion was 48 per cent. The comparable figures were: For the Scott Expedition, 1911, 36 per cent; for the Mawson Expedition, 1912–13, 52 per cent; and the second group of the Scott Expedition at Cape Adare, 1911, 64 per cent. Even though 1929 was a year near the maximum of the sunspot cycle the proportion is considerably below the Cape Adare proportion for a year near sunspot minimum.

A marked feature of the observations of Little America was the progressive change throughout the period of observation of the following phenomena: (a) The average intensity of a display was greatest in April, least in September, and decreased during the period between; (b) the ratio of the number of

displays seen to the number that could possibly have been seen (cloud and light permitting) was greatest in April and decreased throughout the period to September; (c) the proportion of displays at a high altitude was least in April and greatest in September, the proportion increasing slightly through the period; (d) although the majority of displays were seen in the eastern sky, the proportion of those seen in the west increased during the period from April to September; (e) the proportion of displays exhibiting ray-structure, although less than half the total from April to August, increased in September to more than half.

Of the 1412 half-hourly observations, 24 were classed as brilliant, 60 as bright, 321 as moderate, and 1007 as weak or faint. Comparison of auroral character-numbers with the international magnetic character-numbers showed marked evidence for the occurrence of auroral maxima on the same day or one day after maxima in the magnetic character-curve. This has been suggested in a paper by E. O. Hulburt (Phys. Rev., July 15, 1929).

A period of 27 to 28 days is evidenced, corresponding to the period of rotation of the sun and also a short period of about four days. Much has still to be done before complete analysis of the auroral data can be submitted. All members of the Expedition cooperated in the auroral observations. The general interest shown by observers made the direction of the work a very pleasant task. (*Author's abstract.*)

Discussed by Messrs. HULBURT, HECK, GISH, and HUMPHREYS.

E. E. HAGLER, JR.: *The second principle of uncertainty.*

Discussed by Messrs. GIBSON, GISH, and DRYDEN.

G. R. WAIT, *Recording Secretary.*

Obituary

RAOUL GAUTIER, a corresponding member of the ACADEMY, died in Geneva, Switzerland, on April 19, 1931. Previous to his retirement in 1927, he filled the chairs of professor of astronomy and of meteorology at the University of Geneva and was director of the Astronomical Observatory of Geneva. For many years he was a member of the Permanant Commission of the old International Geodetic Association and was largely instrumental in forming, during the World War, the "Association géodésique réduite entre états neutres." Through his efforts, the results obtained at variation-of-latitude stations in California, Japan, and Italy were computed and made available for the use of astronomers. In addition to his other duties he was for many years president of the Swiss Geodetic Commission. His keen intellect, scientific attainments, and personal charm made him a powerful influence for several decades among geodesists of the world, and they, as well as the astronomers, mourn his death.